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THE ONTARIO WATER RESOURCES COMMISSION

REPORT ON

WASTEWATER ASSIMILATION STUDY

KETTLE CREEK

Study - Kettle Creek

TD
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1966
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PARLIAMENT BUILDINGS - TORONTO

TD
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.W378
1966

Wastewater assimilation study :
Kettle Creek.

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WASTEWATER ASSIMILATION STUDY

KETTLE CREEK

WATER QUALITY SURVEYS BRANCH

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PREFACE

Kettle Creek flows in a south-westerly direction through the County of Elgin. The stream is the source of water supply for the City of St. Thomas and further downstream receives the effluent from the St. Thomas water pollution control plant. During drought flow periods the entire discharge from the upper section of Kettle Creek is impounded in the St. Thomas water works reservoir. At these times, streamflow in the lower reach becomes the sum of the discharge from the sewage treatment plant and the flows from two tributaries, Mill and Dodd creeks.

In this report an analysis of the quality conditions under varying streamflows is made and the effect of the anticipated discharge of wastewater from the Ford Motor Company is considered. The evaluation is based on a field survey carried out in August of 1966.

Chapter I presents conclusions resulting from the analysis and recommendations on quality control. Chapter II contains background information and the third chapter deals with the wastewater assimilation analysis. A summary of the results and findings follows in Chapter IV. Detailed supporting material is contained in the report appendices.

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CHAPTER I

CONCLUSIONS AND RECOMMENDATIONS

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CHAPTER I

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on a water quality analysis of Kettle Creek and a study of the use potential of the watercourse as a wastewater receiver, the following conclusions are made:-

1. Water quality in Kettle Creek is seriously impaired by wastewater discharges from the St. Thomas water pollution control plant and Mill Creek.

2. Impoundment of the waterworks reservoirs effectively eliminates the natural streamflow in lower Kettle Creek at St. Thomas during critical summer drought periods.

3. The organic load carrying capacity of Kettle Creek at St. Thomas should be limited to 180 pounds per day (load measured at survey - 240 pounds), to maintain satisfactory quality during critical summer drought flow periods. Assuming elimination of untreated industrial and domestic waste discharges to Mill Creek, the efficiency of the sewage treatment plant would have to be increased to 96 per cent to meet this loading objective.

4. Upstream use for waste disposal by the Ford Motor Co. Ltd. is expected to contribute 10 pounds of BOD_5 per day to Kettle Creek at St. Thomas, and requires an adjustment in the loading rate that can be introduced to the stream at the St. Thomas treatment plant site.

5. The proposed wastewater discharge from the Ford plant to Dodd Creek is expected to cause unsatisfactory quality conditions throughout that stream during periods of drought.

6. As population expands and increased use is made of Dodd Creek by Ford, improved wastewater treatment will be required by the City of St. Thomas and the Ford Company Limited. The feasibility of the following possible measures to meet these demands should be examined:-

    a) the provision of tertiary waste treatment at St. Thomas and the Ford Co. Ltd.

b) streamflow augmentation

c) a combination of a) and b)

d) a trunk sewer serving both St. Thomas and Ford conveying wastes to a treatment plant located on Lake Erie.

RECOMMENDATIONS

1. The sources of untreated industrial and domestic waste discharging directly to Mill Creek should be eliminated.

2. The organic loading carried by Kettle Creek and introduced from the St. Thomas WPCP, Mill Creek, and upstream locations should be limited at the St. Thomas sewage treatment plant site to 180 pounds per day of BOD_5. The economics of following several alternatives for water quality control should be examined for feasibility:

   a) the provision of tertiary waste treatment at St. Thomas and the Ford Co. Ltd.

   b) streamflow augmentation

   c) a combination of a) and b)

   d) a trunk sewer serving both St. Thomas and Ford conveying wastes to a treatment plant located on Lake Erie.

CHAPTER II

INTRODUCTION

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CHAPTER II

INTRODUCTION

Kettle Creek rises twenty-two miles northeast of the City of St. Thomas and flows in a south-westerly direction to the St. Thomas water supply reservoir. From the reservoir, it meanders through the northwest corner of St. Thomas where it is joined by Dodd Creek which flows in from the west. Near the St. Thomas water pollution control plant, Kettle Creek is joined by Mill Creek which enters from the east after flowing through the southern portions of St. Thomas.

The stream continues in a southerly direction until it enters Lake Erie at Port Stanley.

1. PHYSIOGRAPHY(1)

Kettle Creek rises at an elevation of 875 feet above sea level and flows with an average gradient of approximately 9 feet per mile to its confluence with Lake Erie. The gradient suggests quiescent streamflow which is true for the most part, however there are short sections of turbulent flow throughout the length of the stream.

In its lower reach, Kettle Creek flows through a steep-sided, flat-floored valley cut in a sand plain. The valley varies in depth from 125 feet at Port Stanley to less than 75 feet at St. Thomas. The upper reach flows through clay and till plains where the valley is less pronounced.

2. CLIMATE

The mean temperature and annual percipitation for the Kettle Creek Basin are as follows:-

Temperature	-	46°F
Rainfall	-	25 inches
Snowfall	-	100 inches

3. STREAMFLOW

There are no continuous records of streamflow on the lower section of Kettle Creek. The gauge at Southwold Road in St. Thomas

(1) The physiography of Southern Ontario
- Putman and Chapman - U. of T. Press

is read only during spring runoff.

Streamflow in the upper section of Kettle Creek is impounded at the water works reservoir and used as raw water supply for the City of St. Thomas. Often during summer low flow periods all streamflow from Upper Kettle Creek is impounded reducing the natural streamflow in the lower reaches of the stream to zero.

Mill Creek and Dodd Creek are the only tributaries that contribute flow to the stream during the summer months.

4. WATER USE

a) Water Supply

The principal source of water supply for the St. Thomas area is Kettle Creek, however, two wells are maintained to augment the supply during periods of low streamflow.

Prior to distribution, water taken from the St. Thomas water supply reservoir receives pre-chlorination, aeration, coagulation settling, filtration, and post-chlorination. Water obtained from the wells is chlorinated only.

During the August survey the average daily pumpage at the plant was 2.82 mgd. Water works pumpage for 1966 averaged 2.58 mgd.

Kettle Creek is also used to a limited extent for livestock watering and irrigation. The latter is carried out at three locations downstream from St. Thomas on tributaries to Kettle Creek.

b) Wastewater Disposal

The major portions of the developed area of the city including industrial, commercial and residential properties are serviced by combined sanitary-storm sewer systems.

The secondary wastewater treatment plant has a capacity of 4.5 mgd and provides grit removal, primary settling, mechanical aeration, activated sludge treatment, final settling and effluent chlorination. The effluent is discharged through two outfalls to Kettle Creek. Heated sludge digestion and sludge drying are carried out at the plant. Average flow through the plant in 1966 was 2.62 mgd.

Samples collected during the August survey and at other times indicate that the raw sewage entering the plant is very weak with a

BOD_5 level of about 80 ppm. Normally, raw sewage has a BOD_5 concentr of 200 - 250 ppm.

Sanitary sewage from three small residential areas in the north-west end of St. Thomas is collected and treated in septic tanks that discharge to Kettle Creek near the confluence with Dodd Creek.

Several industrial and domestic waste sources discharge wastes directly to Mill Creek.

CHAPTER III

WASTEWATER ASSIMILATION

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CHAPTER III

WASTEWATER ASSIMILATION

1. INTRODUCTION

A modification of the Streeter-Phelps theory describing the effects of decay of organic pollution on the oxygen balance of streams was used in the quality analysis.

A detailed evaluation of the wastewater inputs from the St. Thomas water pollution control plant, Mill Creek, and Dodd Creek was made. Wastes from these sources of pollution were considered to receive thorough mixing to produce uniformity of pollutant concentration over the cross-section of the stream. Accordingly the study of decay of non-conservative pollutants was based on a one dimensional analysis along the longitudinal axis of the stream.

Field stations were located using both distance in miles from the mouth of the creek and the time of travel in hours downstream from the water pollution control plant.

Average water temperatures derived from survey data were employed in calculating values of dissolved oxygen deficits and oxygen saturation.

It was assumed that biochemical oxygen demand removal was primarily effected by biochemical processes and directly proportional to oxygen utilization. Removal by deposition was assumed to be insignificant. The coefficient describing the rate of oxygen utilization is designated by Kd.

No attempt was made to differentiate between the various sources of oxygen in the assessment of the dissolved oxygen balance in the stream. The coefficient of reoxygenation is designated as K_2.

2. FIELD SURVEY

Thirteen stream sampling stations were established commencing at the junction with Dodd Creek, about 1.7 miles upstream from the St. Thomas treatment plant and proceeding downstream approximately 14 miles to Lake Erie. Survey stations are shown in Figure III-1 and described in Table III-1.

The fieldwork required two 3-man crews working 12-hour shifts from August 23 to August 25, 1966. At 4-hour intervals, samples were collected for chemical analysis and bacteriological examination and

measurement made of dissolved oxygen, temperature, and streamflow. Samples of the raw sewage and treatment plant effluent were composited over 12-hour periods. A total of 207 samples were collected for chemical analysis, of which 147 were analyzed for total and carbonaceous 5-day biochemical oxygen demand only and the remaining 60 (all 12-hour composites) for total, suspended and volatile solids; total and soluble phosphorus; free ammonia, total Kjeldahl, nitrite and nitrate.

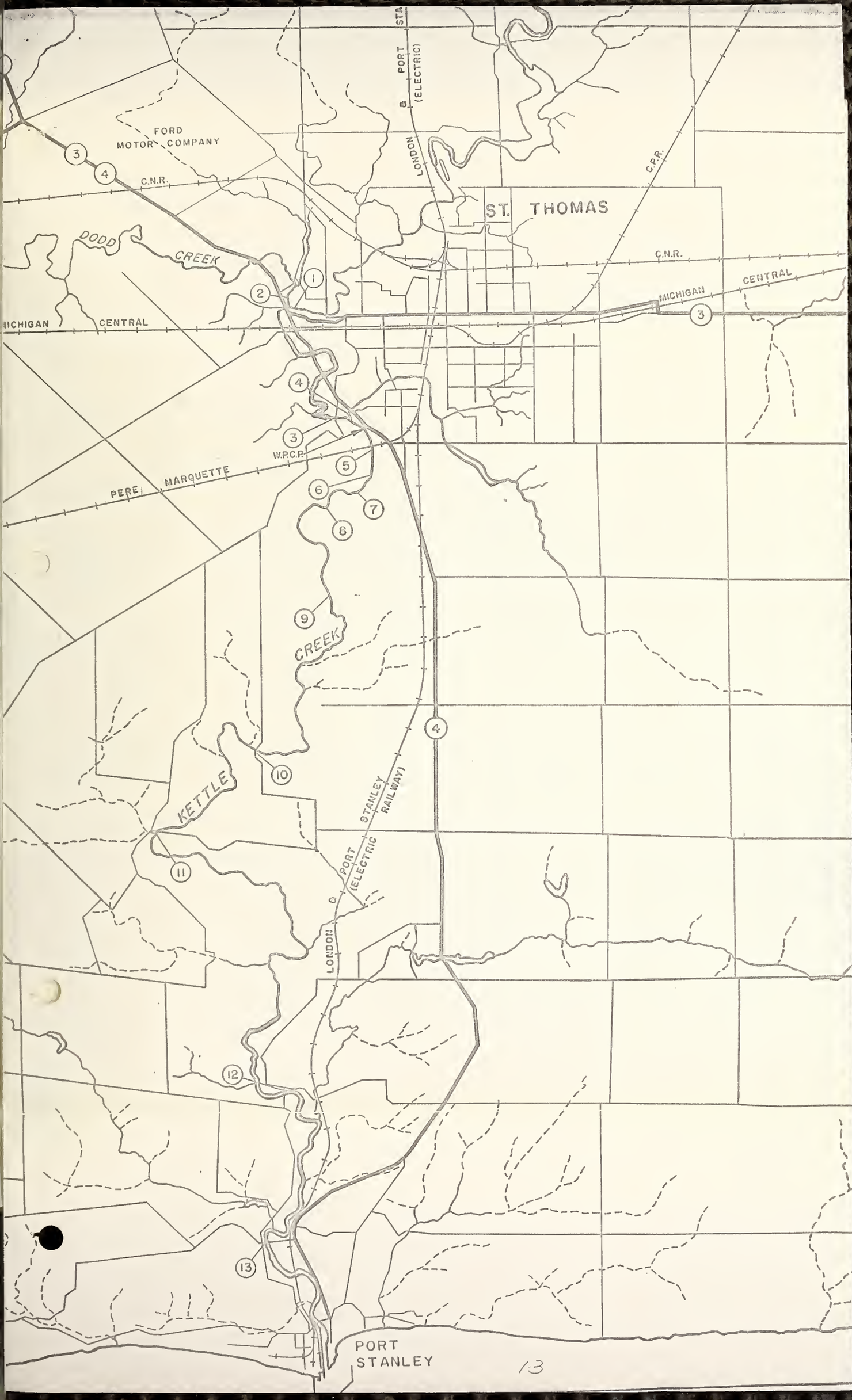
Time of travel was established using Rhodamine WT dye and a fluorometer.

Streamflow measurements were taken regularly at survey stations 1, 2, 4 and 5. Supplementary flow data was collected twice during the survey at station 12. Discharge calculations were made using the velocity-area method. The total flow through the treatment plant was obtained from meter records at the plant.

TABLE III-I

SAMPLING STATION LOCATIONS

Station Number	Mileage	Location	Miles from W.P.C.P.
1	K-13.8	Kettle Ck. above confluence with Dodd Ck.	1.7
2	KD-13.8	Dodd Ck. above confluence with Kettle Ck.	1.7
3	K-12.2	At Southwold St.	0.1
WPCP	K-12.1	Effluent from St. Thomas WPCP	
4	KM-12.1	Mill Ck. above confluence with Kettle Ck.	0.0
5	K-11.8	100' Downstream from C & O R.R.TRESTLE	0.3
6	K-11.5	1500' " " " " "	0.6
7	K-11.3	3000' " " " " "	0.8
8	K-11.0	1 Mile " " " " "	1.0
9	K-10.2	1.8 Miles " " " " "	1.9
10	K-8.2	First Bridge Downstream from W.P.C.P.	3.9
11	K-6.4	Second " " " "	5.7
12	K-2.9	Second Bridge Upstream from Port Stanley	9.2
13	K-1.3	First Bridge Upstream from Port Stanley	10.8


FORD MOTOR COMPANY
C.N.R.
DODD CREEK
ST. THOMAS
LONDON & PORT STANLEY (ELECTRIC)
C.P.R.
C.N.R.
MICHIGAN CENTRAL
MICHIGAN CENTRAL
W.P.C.P.
PERE MARQUETTE
CREEK
KETTLE
LONDON & PORT STANLEY (ELECTRIC RAILWAY)
PORT STANLEY
1
2
3
4
5
6
7
8
9
10
11
12
13

3. PRESENT USE OF KETTLE CREEK FOR WASTEWATER DISPOSAL

Kettle Creek receives organic loadings from two major sources: the St. Thomas water pollution control plant and Mill Creek. In August 1966, at a treatment efficiency of 92 per cent, a loading of 200 pounds of BOD_5 per day was measured in the plant effluent, while Mill Creek contributed about 45 pounds per day of BOD_5.

4. DETERMINATION OF THE NATURAL PURIFICATION CONSTANTS

From a graph plotting the logarithms of pounds of 5-day biochemical oxygen demand versus time of travel on a linear scale, an approximate coefficient of BOD removal was established.

The velocity and mean depth of Kettle Creek was used to obtain an estimate of the value for K_2, the reoxygenation constant.

A dissolved oxygen profile, using these coefficients, Kd and K_2 was plotted. The coefficients were adjusted until close agreement between the field and calculated dissolved oxygen sag curves was obtained (Figure III-2).

The rate constants thus established and used throughout the survey area were:

Kd - 1.32/day at 20°C
K_2 - 0.70/day at 20°C

A mathematical model, permitting calculation of the dissolved oxygen profile under changing flow, temperature and wastewater loading conditions, was established for Kettle Creek below St. Thomas.

5. CALCULATION OF THE ACCEPTABLE ORGANIC LOAD

During summer months when streamflow is low and temperatures elevated, water quality conditions are most critical.

The purpose of this section of the report is to determine the maximum organic load that may be introduced to Kettle Creek during low flow periods such that the dissolved oxygen level in the stream is not reduced below 4.0 ppm.

As mentioned in Chapter II, continuous streamflow records for Kettle Creek are not available. For the purpose of the survey it was necessary, therefore, to make an estimate of probable low flow conditions in the stream. The drought flows selected were:-

Kettle Creek	0.00 cfs
Dodd Creek	0.10 cfs
Mill Creek	1.20 cfs

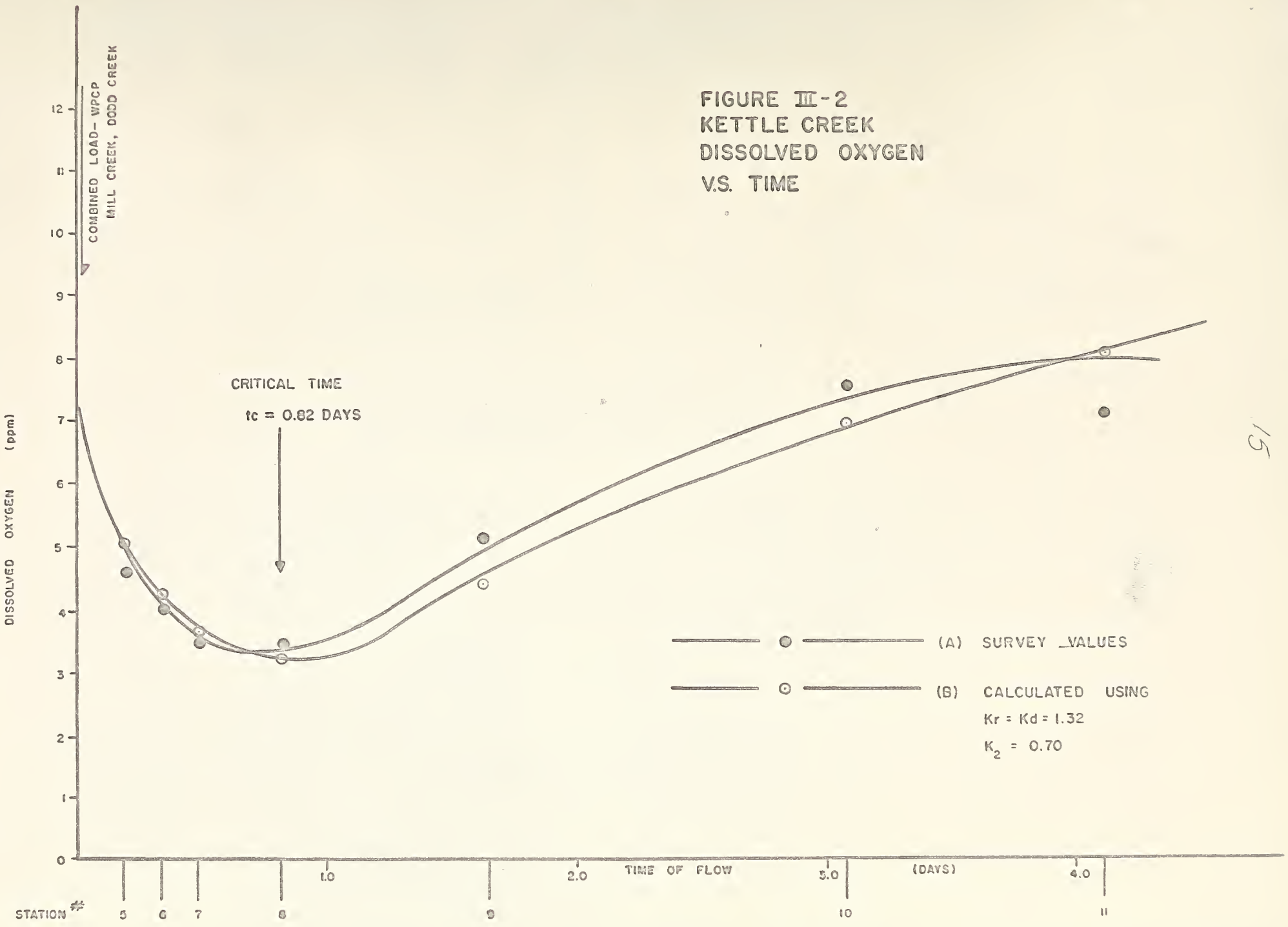


FIGURE III-2
KETTLE CREEK
DISSOLVED OXYGEN
V.S. TIME
COMBINED LOAD- WPCP
MILL CREEK, DODD CREEK
CRITICAL TIME
tc = 0.82 DAYS
DISSOLVED OXYGEN (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
12
STATION #
5
6
7
8
9
10
11
1.0
2.0
3.0
4.0
TIME OF FLOW (DAYS)
(A) SURVEY VALUES
(B) CALCULATED USING
Kr = Kd = 1.32
K2 = 0.70

With the addition of 6.0 cfs from the St. Thomas treatment plant, the total flow in the stream below St. Thomas was estimated to be 7.3 cfs.

Using the following critical conditions, a dissolved oxygen sag curve was calculated (Fig. III-3).

- Streamflow - 7.3 cfs
- Stream temperature - 25°C
- Kd = 1.60/day at 25°C
- K_2 = 0.77/day at 25°C

Table B-1 in Appendix B shows the progress of calculations for the dissolved oxygen profile.

Under the above conditions, an acceptable wastewater loading of 180 pounds BOD_5 per day at the sewage treatment plant was estimated. This load would satisfy the dissolved oxygen objective of 4.0 ppm in Kettle Creek and produce an initial 5-day biochemical oxygen demand concentration of 4.6 ppm in the stream near the plant outfall. The loading objective of 180 pounds could be met only if waste discharges to Mill Creek were eliminated and the plant efficiency increased to 96 per cent.

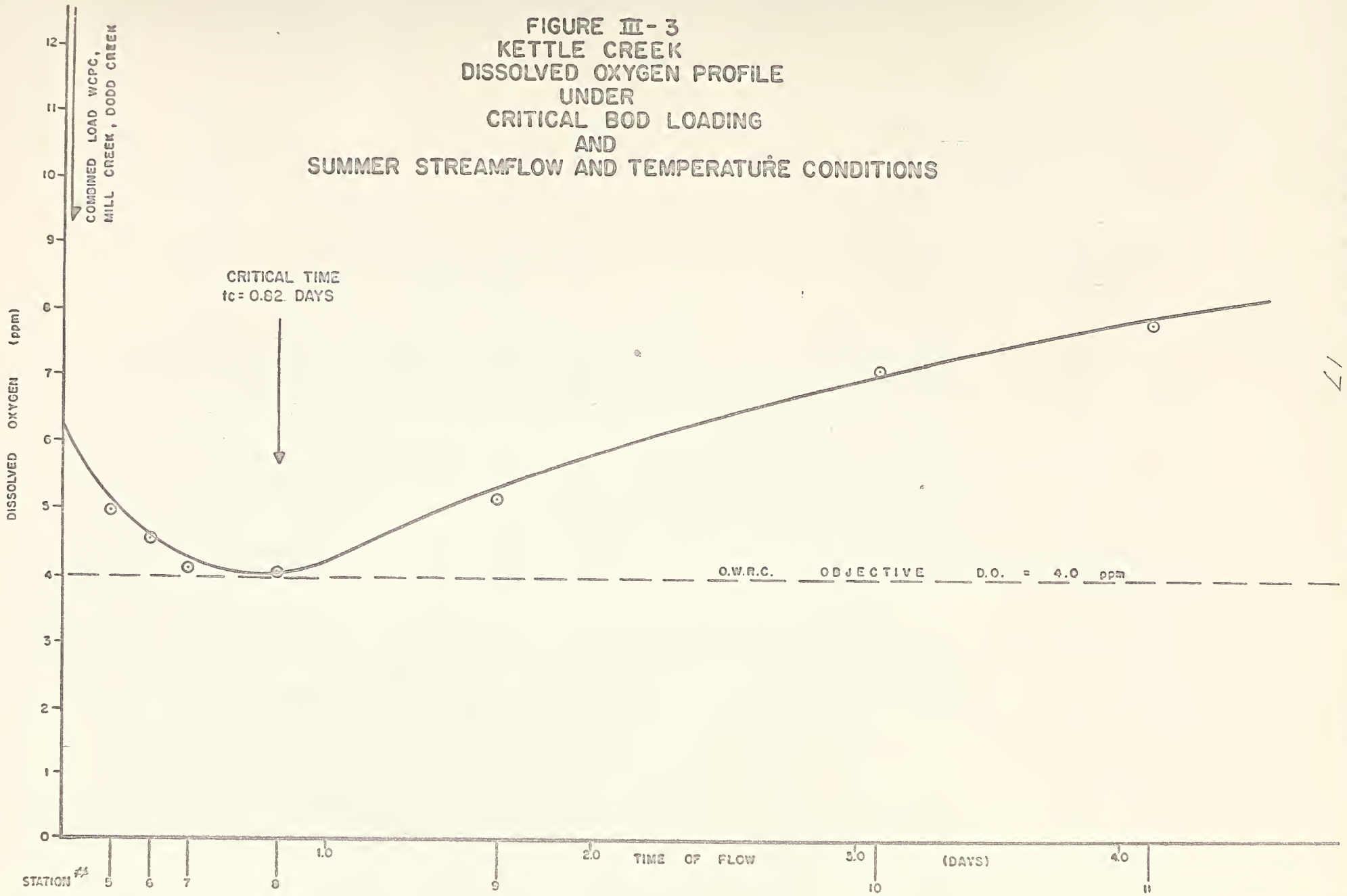
6. FUTURE REQUIREMENTS

a) Ford Motor Company of Canada Limited

Early in 1968, the Ford Motor Company's assembly plant near St. Thomas is expected to be in full production, discharging about 1 cfs of wastewater with a 5-day biochemical oxygen demand of about 10 ppm (54 pounds per day) to Dodd Creek 9 miles upstream from the St. Thomas plant. Assuming natural purification characteristics similar to those established for Kettle Creek and negligible summer flow, the dissolved oxygen levels throughout Dodd Creek would fall below the objective of 4 ppm. Minimum values would be in the order of 1.7 ppm. Natural purification would reduce the BOD_5 to approximately 10 pounds per day at the St. Thomas sewage treatment plant. This would require adjustment in the acceptable loading rate that could be introduced to the stream at the treatment plant site.

Thus, it is expected that the discharge from the Ford holding pond will cause unsatisfactory water quality conditions in Dodd Creek during summer droughts. The effects of the attenuated loading from Ford should be taken into account in making alterations in the capacity of the sewage treatment plant.

FIGURE III-3
KETTLE CREEK
DISSOLVED OXYGEN PROFILE
UNDER
CRITICAL BOD LOADING
AND
SUMMER STREAMFLOW AND TEMPERATURE CONDITIONS



b) St. Thomas

A city population of 41,000 persons is expected by 1986 and an increased load from Ford is probable. Under stream loading conditions significantly greater than those at present, either streamflow augmentation, tertiary waste treatment, or a combination of these will be required to maintain the quality of Kettle Creek. It is expected that this situation will develop in the next few years.

LOW-FLOW AUGMENTATION

Completion of the regional water supply, pipeline and use by St. Thomas will release a minimum streamflow of 4 cfs, now used for municipal water supply for flow augmentation. Maintenance of satisfactory quality conditions would then be maintained providing the daily BOD_5 loading equivalent at the treatment plant site did not exceed 260 pounds per day. To illustrate the value of increased stream flows further, if the St. Thomas reservoir could be designed to provide a flow of 8 cfs during the critical summer drought periods the organic loading equivalent could be increased to about 340 pounds per day without causing unsatisfactory quality conditions.

The need for a detailed study of the hydrology of the upper Kettle Creek basin is indicated to evaluate the feasibility of flow augmentation for quality control.

ALTERNATIVE CONTROL MEASURES

Flow augmentation may be the simplest and most economical solution, however, other alternatives may be considered. The entire effluent from the St. Thomas treatment plant or that portion of the effluent in excess of the allowable waste loading may be transported by trunk sewer to Lake Erie for treatment and disposal.

7. ADDITION OF NUTRIENTS

Nitrogen and phosphorus levels are elevated throughout the Kettle Creek basin, however, concentrations discharged from the treatment plant and at all stations downstream from the outfalls are very high.

An estimate of the annual yield of phosphorus and nitrogen from the Kettle Creek basin suggests that 70 and 40 tons respectively are contributed to Lake Erie. The magnitude and effects of nutrient materials found during the 1966 survey are outlined in Appendix A of this report.

With the expected increase in population in the St. Thomas area,

the addition of nutrients to Kettle Creek and Lake Erie will continue to be a difficult quality control problem. It is expected that tertiary waste treatment to control the input of nutrients will be required in the future.

CHAPTER IV

SUMMARY

CHAPTER IV

SUMMARY

A detailed survey of water quality in Kettle Creek along the reach from St. Thomas to Port Stanley was made in August, 1966.

During the survey period, the St. Thomas water pollution control plant discharged an effluent with an average BOD_5 of 6.2 ppm at 6 cfs, equivalent to a BOD loading rate of 200 pounds per day. As well, Mill Creek contributed 5.5 ppm BOD_5 to Kettle Creek at the rate of 1.8 cfs. Under these loading conditions, quality in the creek was impaired and exceeded the BOD_5 objective of 4.0 ppm throughout the reach. Dissolved oxygen levels were satisfactory except at those stations within a mile downstream of the treatment plant where dissolved oxygen averaged 3.5 ppm and fell to as low as 1.2 ppm on one occasion. Nitrogen and phosphorus levels were elevated throughout the river basin, however, concentrations downstream from the treatment plant were very high.

From the information collected, the rate constants for oxygen utilization and reoxygenation were established and predictions of water quality conditions under varying streamflows made.

It was established that satisfactory quality conditions could be maintained during low flow periods with the organic loading in the stream limited to 130 pounds per day at St. Thomas.

By 1968, the Ford Motor Company assembly plant near St. Thomas should be in full production. It is expected that the discharge of wastewater to Dodd Creek from Ford will seriously reduce dissolved oxygen levels during drought periods and contribute to the BOD content of the creek at the site of the St. Thomas sewage treatment plant. The effects of the attenuated loading from Ford should be considered in future designs of the sewage treatment plant.

The population of the City of St. Thomas in 1986 is expected to be 41,000 persons. Material increases in the wastewater discharge from St. Thomas are expected in the next few years.

With the completion of the St. Thomas water supply pipeline, the discharges from the water works reservoir will become available for low augmentation and stream quality control. The possibility of improving the flow regime in the lower stream by impoundment further upstream should be investigated.

The feasibility of the following water pollution control measures should be investigated.

a) the provision of tertiary waste treatment at St. Thomas and the Ford Co. Ltd.

b) streamflow augmentation

c) a combination of a) and b)

d) trunk sewer serving both St. Thomas and Ford conveying wastewaters to a treatment plant site on Lake Erie.

APPENDIX A

DISCUSSION OF FIELD AND LABORATORY DATA

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APPENDIX A

Discussion of field and laboratory data

Physical & Chemical Parameters

TEMPERATURE

Summary of Temperature Data (^{o}C)

Station	Average	Maximum	Minimum
1	18.8	21	16.5
2	19.4	23	16
3	20.2	22	18
4	20.3	22	18
5	20.8	22	18
6	20.6	22	18
7	20.8	22	18
8	21.0	22	19
9	20.4	22	18
10	20.0	22.5	18
11	20.0	22	18
12	20.2	22	18
13	20.4	22	19
STP (New)	22.3	24	20
STP (Old)	21.9	24	18

For calculation purposes an overall average temperature of $20^{o}C$ was assumed.

DISSOLVED OXYGEN

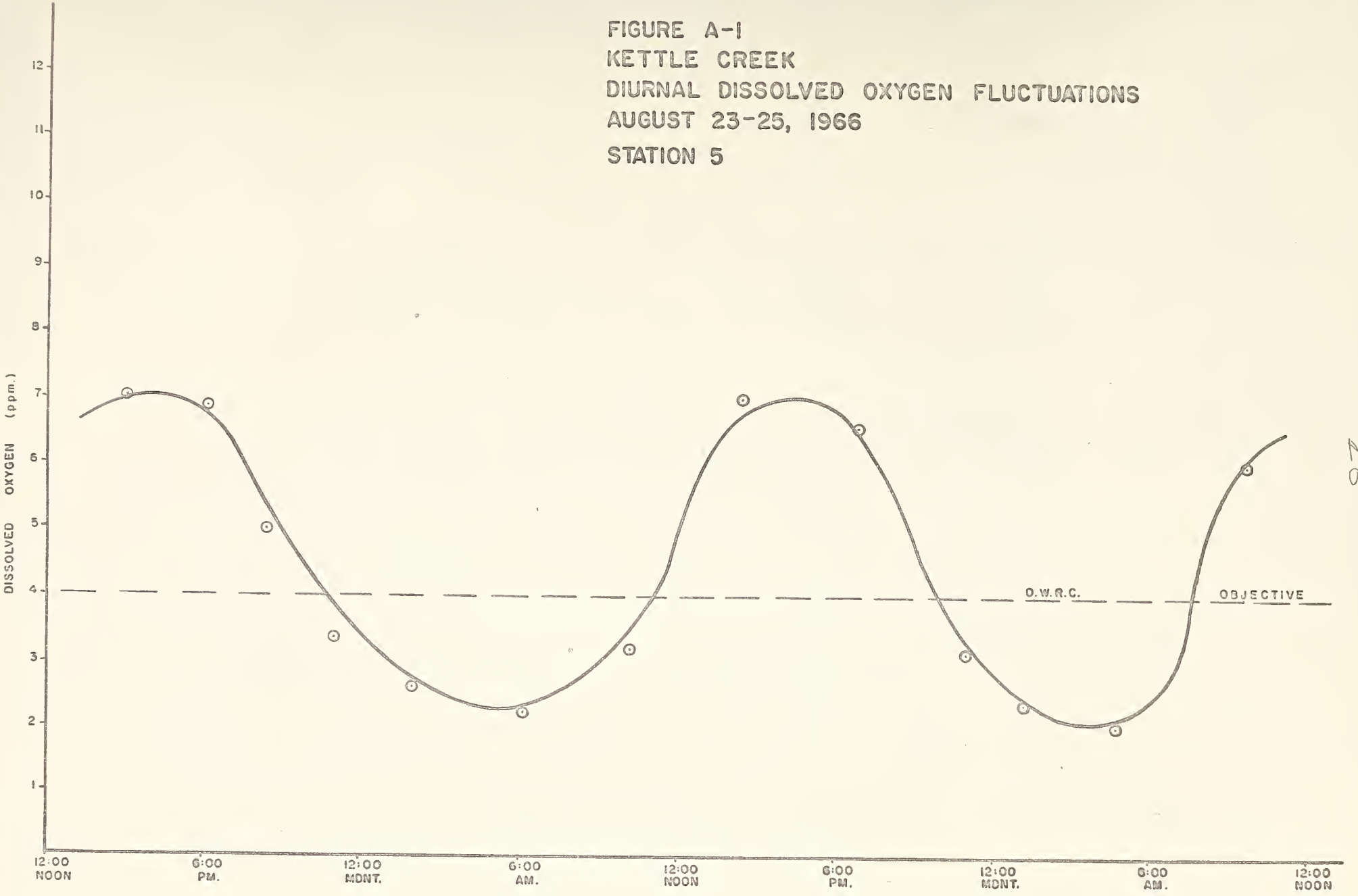
Summary of Dissolved Oxygen Data

Station	Av Temp °C	D.O. Concentration (ppm)			Av. % Sat.	Average D.O. Deficit	
		Av.	Max.	Min.		ppm	#/day
1	18.8	6.5	11.2	3.0	69.2	2.9	5.8
2 (Dodd Ck)	19.4	8.3	17.0	1.8	89.3	1.0	0.8
3	20.2	10.6	18.0	6.6	116.3	-1.5	-4.1
STP (New)	22.3	6.9	7.8	4.0	78.4	1.9	41.1
4 (Mill Ck)	20.3	5.5	8.0	3.8	60.5	3.6	35.5
STP (Old)	21.9	3.8	4.6	3.2	42.7	5.1	55.1
5	20.8	4.5	8.0	2.0	50.0	4.5	180.0
6	20.6	3.8	5.4	2.0	41.8	5.3	211.8
7	20.8	3.4	6.2	1.2	37.8	5.6	223.8
8	21.0	3.4	6.4	1.6	37.8	5.6	223.8
9	20.4	4.9	8.4	2.8	53.8	4.2	170.1
10	20.0	7.4	13.6	1.8	80.4	1.8	73.8
11	20.0	7.1	9.8	6.2	77.2	2.1	87.4
12	20.2	6.8	8.4	4.8	74.7	2.3	97.2
13	20.4	9.9	14.2	6.2	108.8	-0.8	-33.8

OWRC Dissolved Oxygen Stream Objective - Not Less Than 4.0 ppm.

The wide fluctuations in dissolved oxygen observed throughout the survey area are attributed to algal activity.

FIGURE A-1
KETTLE CREEK
DIURNAL DISSOLVED OXYGEN FLUCTUATIONS
AUGUST 23-25, 1966
STATION 5



Dissolved oxygen levels downstream from the WPCP were depressed as low as 1.2 ppm (13.3% saturation) at Station 7. The stream recovered between Stations 7 and 10 with D.O. levels increasing to 80% saturation.

Figure A-1 shows the effects of photosynthesis and plant respiration on oxygen levels.

BIOCHEMICAL OXYGEN DEMAND

An analysis of the collected BOD data reveals an increase in BOD levels downstream from St. Thomas, after the introduction of the municipal sewage treatment plant load. Total and carbonaceous BOD levels remain stationary between Stations 5 and 8, increase at Stations 9 and 10, and show a decreasing trend toward the lake. The rise in BOD at Stations 9 and 10 is attributed to two main factors: nitrification and algae respiration.

Summary of BOD_5 Data

Station	Average (ppm)	BOD_5 (#/day)	Carb. BOD_5* (ppm)	Maximum BOD_5 (ppm)	Minimum BOD_5 (ppm)
1	4.0	8.0	2.1	8.0	1.8
2 (Dodd Ck)	3.2	2.6	2.1	5.8	1.8
3	6.7	18.1	4.6	14.0	3.6
STP (New)	2.8	60.5	1.5	3.0	2.6
4 (Mill Ck)	4.5	43.7	2.6	7.2	2.6
STP (Old)	13.0	141.0	3.6	14.0	12.0
5	5.2	207.8	2.6	7.0	3.4
6	4.8	191.8	2.6	7.4	3.2
7	5.1	203.8	2.7	8.0	3.6
8	5.1	203.8	2.8	7.0	4.0
9	7.8	316.0	3.8	15.4	5.2
10	8.0	328.0	4.0	18.0	3.6
11	5.4	224.5	2.7	7.6	4.0
12	4.0	169.0	2.1	5.2	2.0
13	4.2	177.0	2.9	8.2	2.0

* Nitrification Inhibited

NUTRIENT MATERIALS

Summary of Nitrogen and Phosphorus Data

Station	Nitrogen as N				Phosphorous as PO_4	
	Total Kjeldahl (ppm)	Ammonia (ppm)	Nitrite (ppm)	Nitrate (ppm)	Total Phos. (ppm)	Soluble Phos. (ppm)
1	1.35	0.35	0.03	0.05	1.18	1.05
2(Dodd Ck)	0.82	0.09	0.03	0.09	0.61	0.44
3	1.55	0.16	0.02	0.03	1.57	1.12
STP (New)	1.49	0.11	0.01	15.4	15.7	15.6
4(Mill Ck)	1.33	0.55	0.20	0.70	4.30	3.66
STP (Old)	15.4	7.38	0.08	4.00	14.4	14.3
5	3.73	1.80	0.12	3.23	10.0	9.8
6	3.67	1.80	0.14	4.48	9.2	9.1
7	4.53	2.13	0.20	3.48	9.0	8.3
8	3.23	1.92	0.22	2.97	8.30	7.87
9	2.50	1.67	0.20	3.90	7.50	7.10
10	2.60	1.38	0.22	2.67	8.73	7.87
11	2.60	1.82	0.27	3.42	11.4	10.7
12	1.61	1.05	0.19	2.88	9.15	9.05
13	1.75	0.36	0.04	1.25	4.60	4.30

Domestic sewage contains a significant amount of protein matter which is relatively rich in organic nitrogen and phosphorous compounds. Modern sewage treatment methods including the activated sludge process are relatively inefficient in removing these materials.

Nitrogen and phosphorous are necessary for plant growth. However, excessive nutrient quantities may accelerate the aquatic plant growth under suitable environmental conditions and result in excessive algae which in turn may seriously deplete the dissolved oxygen content when the photosynthetic process is reversed during the night hours.

Phosphorous and nitrogen are present in very high concentrations downstream from the St. Thomas treatment plant causing profuse algae growth in the stream. A general reduction in concentrations towards the mouth of the stream may be attributed to dilution. The sharp increase in phosphorous and nitrate at Station 11 could not be substantiated.

SOLIDS

Summary of Solid Concentrations

Station	Total Solids (ppm)	Suspended Solids (ppm)	Volatile Solids (ppm)
1	425	22	5
2 (Dodd Ck.)	446	15	5
3	460	90	10
WPCP (New)	521	11	6
4	410	11	5
WPCP (Old)	522	11	9
5	479	22	7
6	475	21	8
7	481	20	10
8	463	30	16
9	389	30	8
10	397	25	8
11	459	45	8
12	560	108	12
13	466	67	18

Coliform Bacteria Content

To reduce the effects of extreme values, logarithmic averages of the Membrane Filter (MF) total coliform counts were calculated. High average coliform populations were observed throughout the survey section, falling below the Commission objective of 2400 per 100 ml at Stations 12 and 13 only.

Summary of Coliform Data

Station	MF Coliform per 100 ml Logarithmic Average	Maximum	Minimum
1	21,400	150,000	4,700
2 (Dodd Ck)	17,800	140,000	7,000
3	137,000	48,000	7,000
WPCP (New)	246,000	460,000	132,000
4 (Mill Ck)	114,000	151,000	58,000
WPCP (Old)	132,000	210,000	82,000
5	94,900	113,000	78,000
6	96,000	145,000	39,000
7	118,000	300,000	71,000
8	122,000	141,000	88,000
9	180,000	410,000	79,000
10	112,000	970,000	9,500
11	58,800	144,000	21,000
12	1,620	3,200	660
13	1,520	3,900	1,010

STREAMFLOW

Stream velocities were measured using a Gurley current meter (Model 622) and streamflow was calculated by the velocity-area method.

Summaries of Average Streamflows

Station	Drainage Area sq. mi.	Flows Average (cfs)
1	73.6	0.37
2 (Dodd Ck.)	55.7	0.15
3	132.4	0.50
WPCP (New)	-	4.0
4	8.5	1.8
WPCP (Old)	-	2.0
5	141.1	7.4
6	141.2	7.4
7	141.4	7.4
8	142.0	7.4
9	143.4	7.5
10	146.5	7.6
11	149.0	7.7
12	156.8	7.8
13	170.9	7.9

TIME OF TRAVEL

Summary of Time of Travel

Reach	Point to Point (Days)	Cumulative Time (Days)
WPCP-5	0.20	0.20
5-6	0.14	0.34
6-7	0.14	0.48
7-8	0.35	0.83
8-9	0.82	1.65
9-10	1.40	3.05
10-11	1.02	4.07
11-12	2.0 (estimated)	6.07(estimated
12-13	Backwater effects prevented determination.	

APPENDIX B

WASTEWATER ASSIMILATION FORMULAE

AND

SAMPLE CALCULATIONS

APPENDIX B

WASTEWATER ASSIMILATION FORMULAE AND SAMPLE CALCULATIONS

The following briefly outlines the formulae used in wastewater assimilation calculations and the meaning of the terms employed.

Do = the dissolved oxygen deficit at the point of pollution or the point of reference

Dt = the dissolved oxygen deficit at time t (in days) from the point of reference

Lo = the first stage BOD at the point of reference

t = Time of travel (days)

tc = time of travel to minimum point on the oxygen sag profile

Kd = coefficient of deoxygenation

K_2 = coefficient of reoxygenation

With known values of Do, Lo, K_d, and K_2, the oxygen deficit (D), may be computed for any time (t) downstream by the following equation:

$$D = \frac{Kd\ Lo}{K_2 - Kd} \left(e^{-Kdt} - e^{-K_2 t}\right) + Do\ e^{-K_2 t}$$

The dissolved oxygen can thus be calculated and plotted as a continuous curve against time to form the oxygen profile.

The complete calculation of the sag curve is time-consuming, and since in many cases the critical point is of interest only, the following formula for calculating tc was developed.

$$tc = \frac{1}{K_2 - Kd} \ln \frac{K_2}{Kd} \left[1 - \frac{Do}{Lo} \frac{K_2 - Kd}{Kd}\right]$$

The coefficient of reoxygenation (K_2) is established using the average depth and velocity of a stream cross-section.

$$K_2 = \frac{(DL\ V)^{\frac{1}{2}}}{H\ 3/2} \qquad \text{(Base e)}$$

Where

DL = Oxygen diffusivity coefficient - 0.81×10^{-4} sq.ft/hour at 20°C.

V = Average velocity in feet per hour

H = Average depth in feet

TABLE B-1

KETTLE CREEK SURVEY - AUGUST, 1966

COMPUTATIONS OF THE DISSOLVED OXYGEN PROFILE @ 7-Day - 20 Year Return Low Flow
Temperature - 25°C Kd = 1.60 per day K_2 = 0.77 per day

Station (1)	t Days (2)	-Krt C (3)	$-K_2t$ C (4)	Lo #/day (5)	$\frac{Kd\ Lo}{K_2-Kr}$ (6)	3-4 (7)	6+7 (8)	D #/day (9)	9+4 (10)	8+10 (11)	Q cfs (12)	D (ppm) (13)	D.O. (ppm) (14)
WPCP	0.0	1	1	258	-497	0	0	78.8	78.8	78.8	7.3	2.0	6.4
5	0.2	.726	.865	258	-497	-.139	69.1	78.8	68.2	137.3	7.3	3.5	4.9
6	0.34	.581	.770	258	-497	-.189	94.0	78.8	60.7	154.7	7.3	3.9	4.5
7	0.48	.464	.692	258	-497	-.228	113.3	78.8	54.6	167.9	7.3	4.3	4.1
8	0.83	.262	.528	258	-497	-.263	130.8	78.8	41.6	172.4	7.3	4.4	4.0
9	1.65	.072	.281	258	-497	-.209	104.0	78.8	22.2	126.2	7.3	3.2	5.2
10	3.05	.008	.096	258	-497	-.088	43.7	78.8	7.6	51.3	7.3	1.3	7.1
11	4.07	.002	.044	258	-497	-.042	20.9	78.8	3.5	24.4	7.3	0.6	7.8

APPENDIX C

ABBREVIATIONS

APPENDIX C

ABBREVIATIONS

cfs	-	Cubic feet per second
cfs/sq.mi.	-	Cubic feet per second per square mile
BOD_5	-	5-Day Biochemical Oxygen Demand
D.O.	-	Dissolved Oxygen
^oC	-	Degrees Centigrade
^oF	-	Degrees Fahrenheit
ft	-	Feet
lbs	-	Pounds
M.F.	-	Membrane Filter
mgd	-	Million gallons per day
%	-	Percent
ppm	-	Parts per million

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